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Management of technology: themes, concepts and relationships

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Abstract

In this paper, bibliometric (co-citation analysis) and social network analysis techniques are used to investigate the intellectual pillars of the technology management literature as reported in Technovation. Network analysis tools are also used to show that the research agenda of scholars from different parts of the world differ substantially from each other, and it is argued that such differences may have exacerbated the delays experienced in developing technology management as a respected academic discipline.
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1. Introduction

Over the last two decades technology management (TM) has gradually established itself as an academic discipline. For example, Drejer (1997) identifies four schools of thought as the discipline evolved from R&D Management, through Innovation Management and Technology Planning before developing as Strategic Management of Technology (MOT). Under this classification, MOT is distinct from economics and public policy and is solidly located within the management field. This establishment of a discipline has been a slow process probably as TM researchers prefer to publish their best work in more established journals—such as *ASQ, Management Science, the Academy of Management Journal, Harvard Business Review and Strategic Management Journal*—typically associated with competing fields (Cheng et al., 1999). The importance of publishing in established and respected journals only partially explains why career conscious academics hesitate to submit their ideas to TM-specific journals.

Ambiguity on discipline location and roots relate back to its very early development. For example, Brockhoff (2003)

plots the roots of TM back to the philosophical writings of Francis Bacon's 17th century ideas concerning the organization of inquiry and also discusses the significance of the engineering perspective and its associated investigations which followed the establishment of industrial research and development laboratories about a century ago. However, in common with ideas assigned to most other philosophical or physical science perspectives, these view invention as an art with technical progress dependent upon the ingenuity of single persons. Brockhoff continues by discussing the influence of the Schumpeterian view of the innovator as entrepreneur, which represents a perspective often viewed as a contribution form management planning (Solow, 1957). Exploring more recent developments also show a similar contradiction in discipline location for TM. The focus before the mid 1970s was largely in the hands of practitioners and governmental authors (Allen and Sosa, 2004) with business schools taking over in the 1980s when managing technology became considered as a competitive advantage (US National Research Council, 1987) and the management of technology educational programmes finally emerged 'to mainstream business management during the 1990s' (Nambisan and Wilemon, 2003).

As such, the major obstacle to the development of a TM tradition lies in the subject's unusually high degree of interaction with other disciplines. This overlap blurs the boundaries of TM and as a result its distinct theoretical models and analytical tools are unjustly attributed to competing fields. The review by Garcia and Calantone

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(2002) shows this rather graphically in their analysis of innovation terminology. This confusion, we argue, will be further exacerbated if there are substantial differences in interests and approaches by TM scholars in different parts of the globe. Without cross-fertilisation of ideas between authors on both sides of the Atlantic and elsewhere, recognition of what the discipline stands for will be that much more difficult to obtain.

This paper empirically investigates the issues arising from the struggle to establish TM by examining its literature using citation and co-citation data obtained from *Technovation*. A brief review of similar bibliometric studies is presented to introduce the approach, along with a description of the data. The principal investigation was a factor analysis which was performed to determine the latent structure underlying the TM literature. The view of the TM literature which this analysis produces is discussed and a simple non-parametric technique is used to test the geographic dichotomy.

2. Studies of the academic literature

There are a number of techniques that can be used to examine a body of literature. Most frequent is the simple literature review where a highly subjective approach is used to structure the earlier work (Drejer, 1996, 1997). More objective, quantitative techniques are also available and use an analysis of author citations, co-citations (or a combination of the two) and systematic review. Citation analysis is based on the premise that authors cite papers they consider to be important to the development of their research. As a result, heavily cited articles are likely to have exerted a greater influence on the subject than those less frequently cited (Sharplin and Mabry, 1985; Culnan, 1986). As such these analyses represent 'the field's view of itself' (White and Griffith, 1981). There are well defined concerns surrounding citation analysis, including the problem that a study may be heavily referred to due to its poor quality. However, with adequate screening and a sufficiently large sample, citation analysis provides a useful insight into which papers and authors are considered influential. Similarly, co-citation analysis involves analysing the frequency with which two citations appear together in the literature (Small, 1973). The approach is instrumental in identifying groupings of authors, topics, or methods and can help us understand the way in which these clusters relate to each other.

A number of bibliometric analyses have been performed on the literatures of fields adjacent to TM. For example, Culnan (1986) used co-citation analysis to investigate the founding pillars of management information systems and found the subject to have more affinity with information science than organisation studies. Similarly, Karki (1996) examined the sociology of science literature and found that information scientists and sociologists exchange ideas only

when they are discussing 'scholarly communication' as a subject. Pilkington and Liston-Heyes (1999) have also examined the sub-fields in operations management. To the best of our knowledge no such study has dealt with the field of TM, with the closest being Cottrill et al's (1989) investigation of the links between 'diffusion theory' and 'technology transfer'. Somewhat surprisingly, they found the use of distinct approaches within each sub-field but that they rarely interacted with each other.

With regards to the second objective of this study—assessing whether scholars from different regions are interested in the same TM issues—we follow in the footsteps of Usdiken and Pasadeos (1995) who tested the literature of Organisational Analysis for a similar geographical division. They found that the field's two major journals, the North American produced *Administrative Science Quarterly*, and the UK edited *Organisation Studies*, almost exclusively published the work of local authors who were similarly parochial in their citation practices. This approach was adapted by Pilkington and Liston-Heyes (1999) and found a noticeable difference between the interests of North American and European scholars and their research traditions in operations management.

3. Methodology

The data used in this study included the contents (article titles, authors, publication dates, and citations) of *Technovation* between 1996 and 2003. *Technovation* was selected on the basis of its prominence in the field, wide geographical coverage, and ease of access because of its inclusion in the on-line version of the Social Science Citation Index (SSCI). This is a somewhat imperfect record of the literature which should ideally include the contents or partial contents of other journals such as *Research Policy, R&D Management, Decision Science, Management Science, IEEE Transactions on Engineering Management,* and *Journal of Engineering and Technology Management (JETM)*. However, it was felt that the wide range of topics covered by the articles in these journals and the differences in readership focus would necessitate a manual and time consuming classification of the articles to identify those relevant to TM. Also, as there were no citation data in the SSCI for *Technovation* before 1996, it was decided to limit the scope of the sample to the articles appearing in *Technovation* from Volume 16, Number 10, 1996 to Volume 23 Number 12, 2003.

One concern with the data selection and recovery phase of the work revolved around some omissions in the SSCI database. Whilst there are records for every issue between these dates, they contain an uneven number of articles, and some entries, such as January and October 1997, list only one article. Therefore, it is evident that the SSCI records are incomplete. However, despite there being no discernable reason as to why some articles were missing, it was thought that this represents a sampling effect rather than any